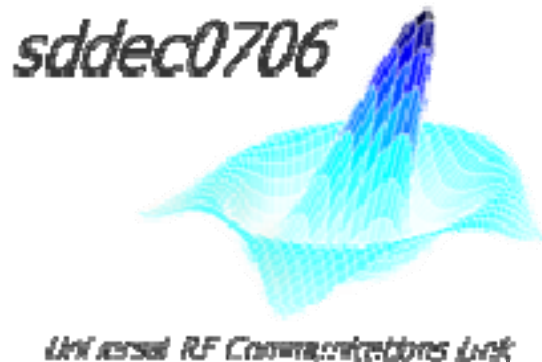


UNIVERSAL COMMUNICATIONS LINK

SERVICE MANUAL



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About This Manual

This manual contains information for assembling and testing the communications link developed by the ECE senior design team Dec0706.

This manual requires that you have a basic understanding of interrupting schematics and are proficient in soldering a printed circuit board.

Related Documentation

The following documents contain information that you might find helpful as you use the communications link.

- The Universal Communications Link final report
- The Universal Communications User Manual

The following resources contain information about concepts and products related to the communications link.

- nRF24L01 Single Chip 2.4GHz Transceiver
- MSP430x16x Mixed Signal Microcontroller

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Introduction

1

The Universal Communications Link was developed as a short-range 2-way wireless data link for other senior design teams' use. The communications link contains components for handling user's data input, buffering incoming RF data while sending outgoing RF data, and servicing user's commands through an interface.

The dynamic system, shown in Figure 1-1, refers to the combination of the user and the communications link.

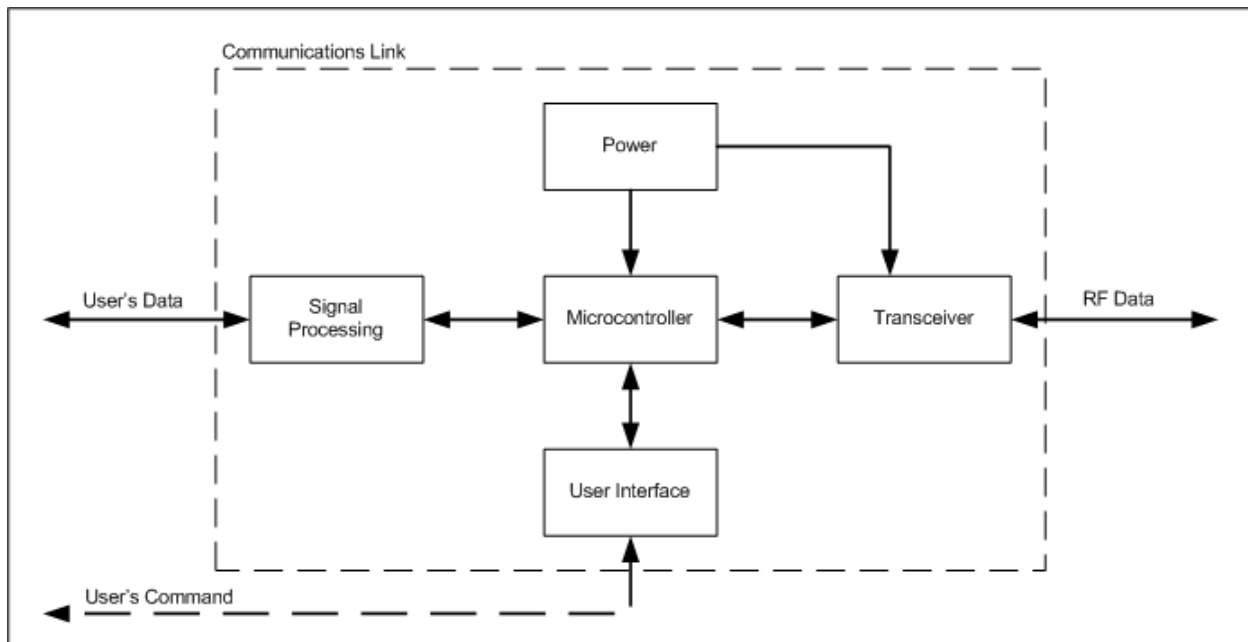


Figure 1-1 Dynamic System

The dynamic system in Figure 1-1 represents a 2-way communication system. In operation, user's data is received from the adjacent link and transmitted to the adjacent link at the same time.

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Assembly

2

The Universal Communications Link can be assembled by hand using a soldering iron. It is recommended that the user be familiar with soldering surface mount. Some difficulty may be encountered when soldering the transceiver integrated chip.

Schematics

The schematics were created using Cadsoft Eagle version 4.16, and can be viewed on the following pages.

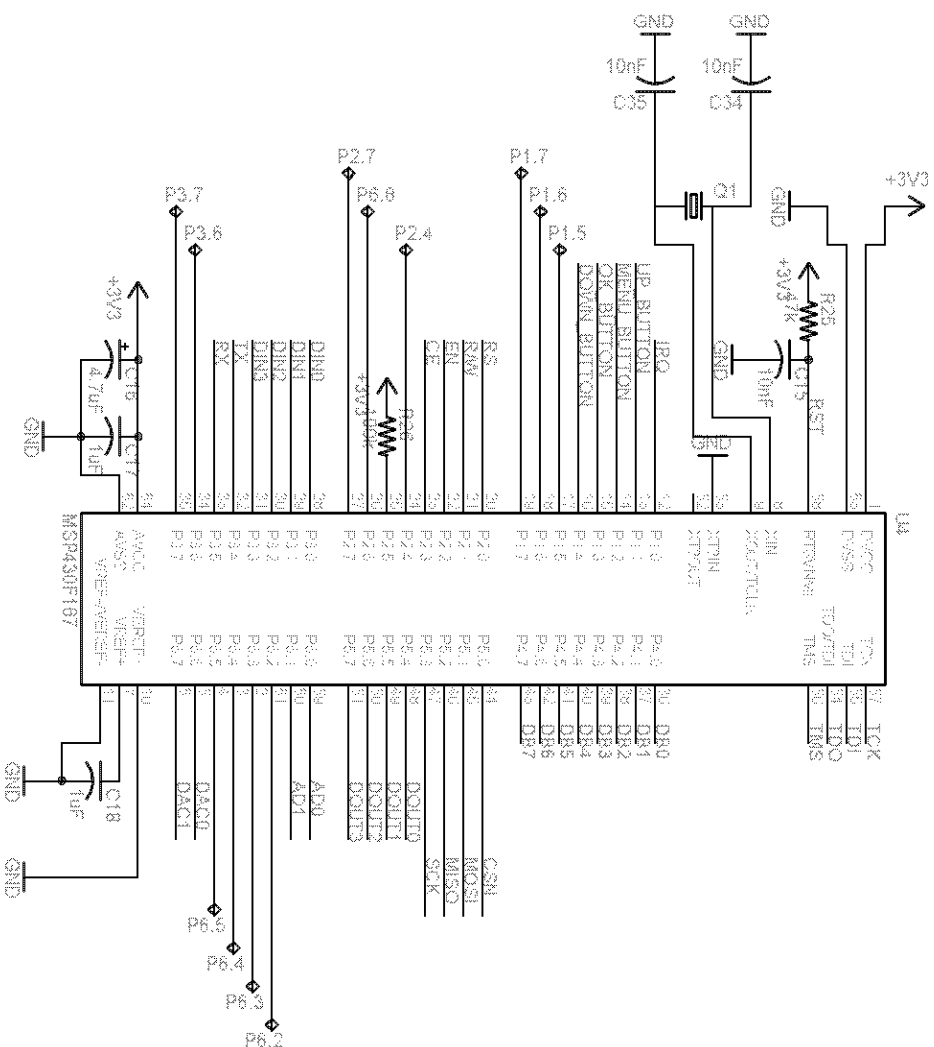
PCB Artwork

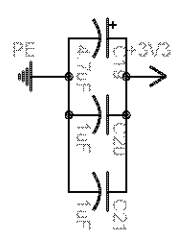
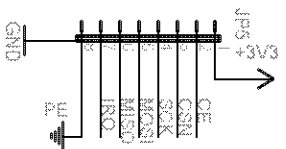
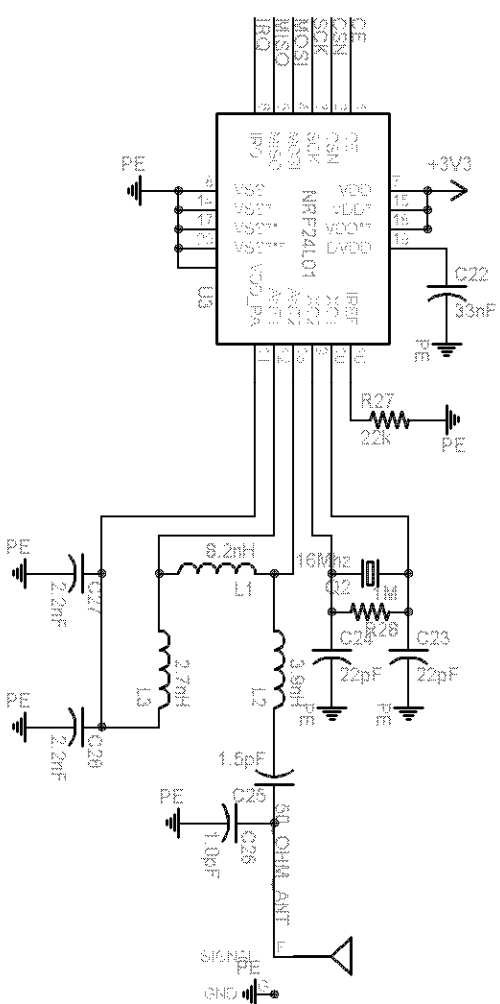
The PCB artwork was created using Cadsoft Eagle version 4.16, and can be seen in Figure 2-2 and Figure 2-1.

Assembly Procedure

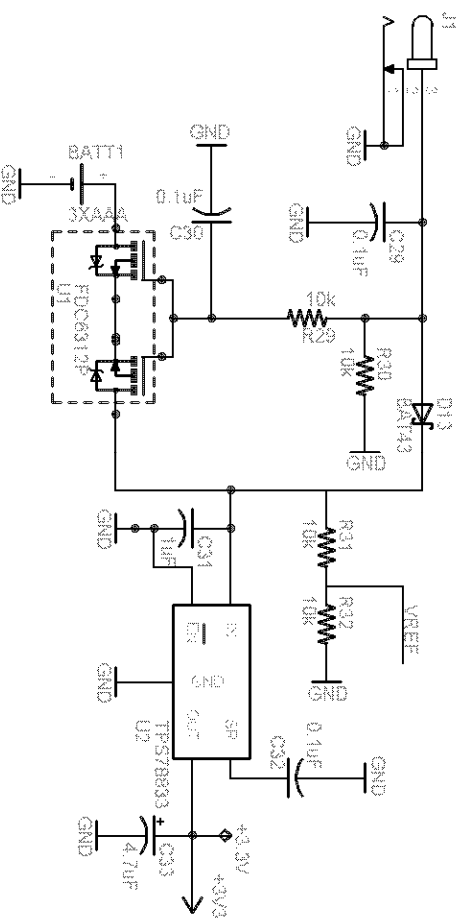
It is recommended to assemble the communications link in this order.

- o Reflow nRF24L01 transceiver IC
- o Solder 0402 components
- o Solder power subsystem circuitry
- o Test supply current; should not exceed 15mA
- o Solder msp430f167 microcontroller IC
- o Test supply current; should not exceed 15mA
- o Solder remaining IC
- o Solder 0805 components
- o Solder tactile switches and remaining components
- o Test supply current; should not exceed 20mA





Transceiver		
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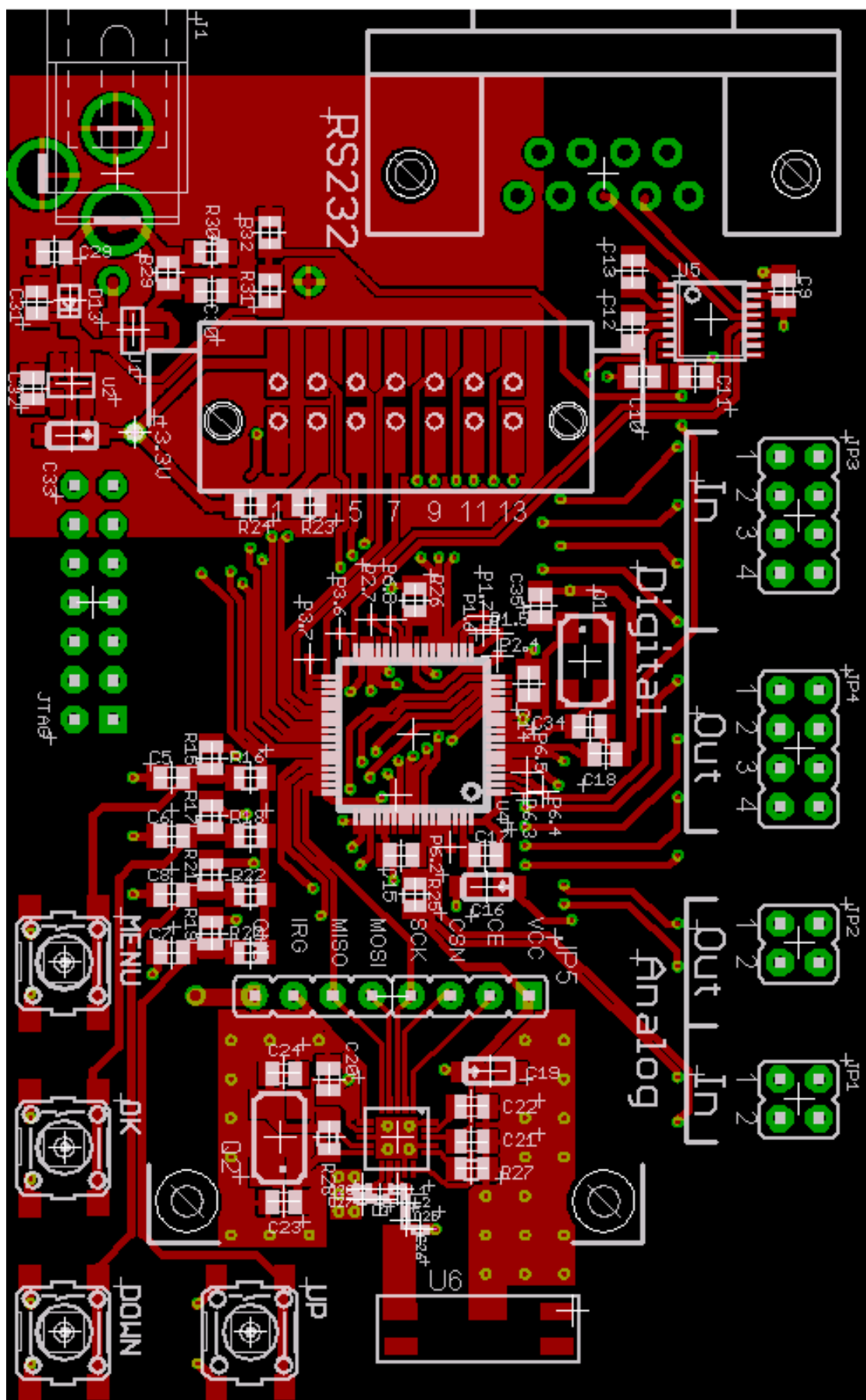


Figure 2-1 PCB Top Side

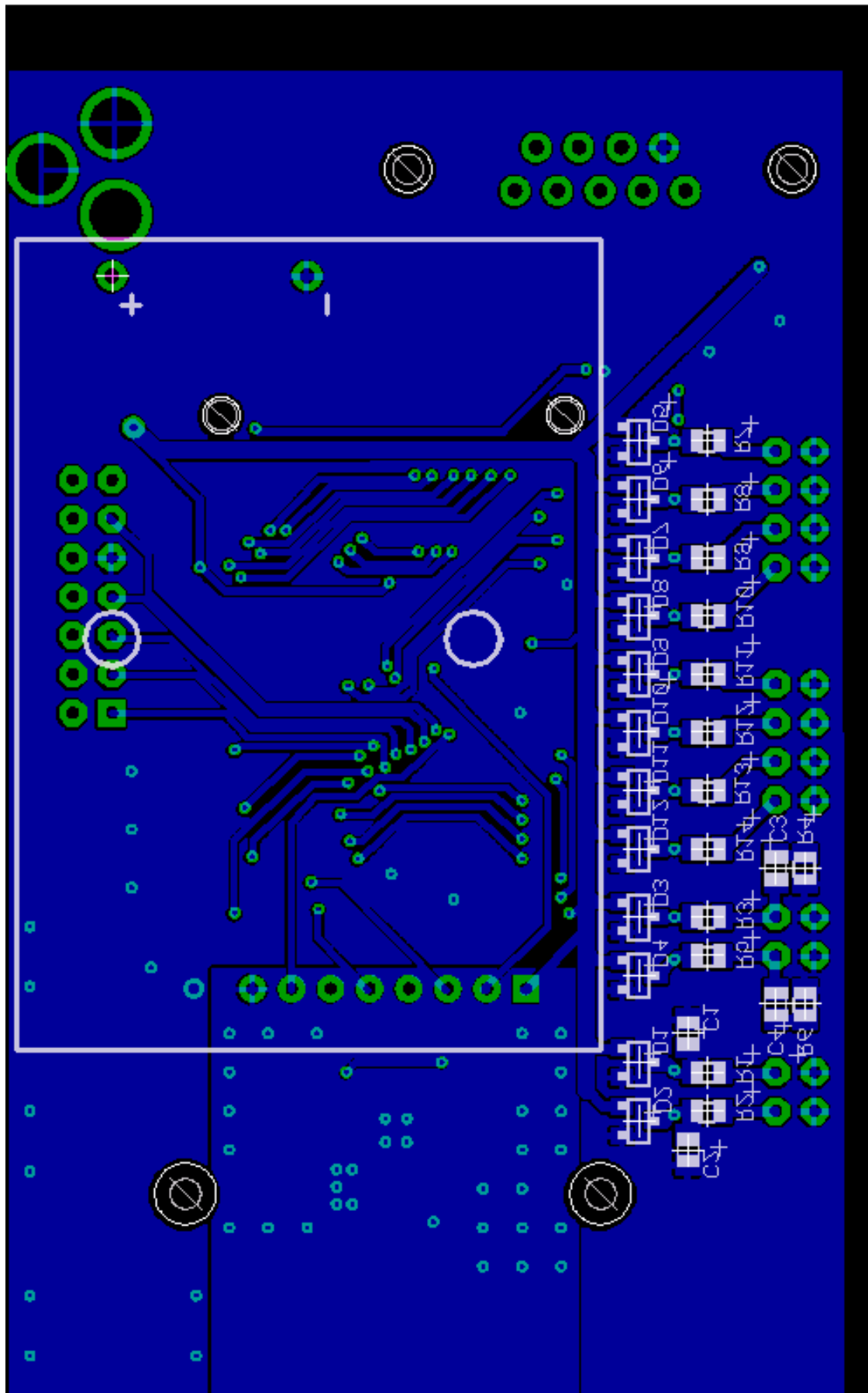


Figure 2-2 PCB Bottom Layer

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Programming

The Universal Communications Link is programmed through the JTAG connector located just below the LCD.

Sampling and Reconstruction

Every 125 μ s, an interrupt is triggered by a hardware timer resulting in a sample rate of 8 kHz. This interrupt samples the module's analog and digital inputs, updates the analog and digital outputs, and is responsible for all communication between the microcontroller and the transceiver IC.

The microcontroller's internal ADC has the capability to chain multiple conversion requests together so that they are initiated by a single trigger. Using this feature the ISR can read the results from the previous ADC conversions immediately instead of having to initiate four (analog input 1, analog input 2, battery voltage, and temperature) conversions independently and wait for them to finish. After reading the conversion results, the next series of conversions is initiated and the ISR continues without blocking.

Air Protocol

The transceiver supports three modes: transmit, receive, and standby. While in transmit or standby mode the transceiver is unable to decode incoming packets. To account for this, time slot synchronization is used to synchronize transmission times between two radios. In each 1.5ms period, 750 μ s are allocated to each radio to transmit.

Since the radios operate in the 2.4GHz band the protocol must tolerate Bluetooth traffic. Bluetooth devices frequency hop between packet transmissions, meaning that Bluetooth traffic may collide with traffic from the radio modules. To improve its tolerance to these collisions as well as to add a level of data redundancy, the air protocol transmits each packet twice. The retransmission always occurs during the next transmission time slot, or approximately 1.5ms later. Bluetooth packets may last up to 850 μ s, after which the device will hop to another frequency. Delaying the retransmission longer than this improves the chances of the packet reaching its destination.

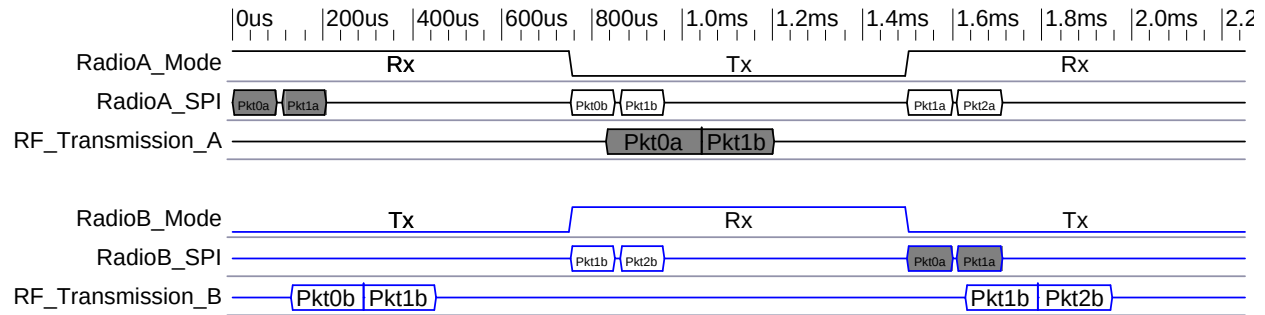


Figure 3-1 Timing Diagram

The figure above describes the data path for two packets (grey) from radio A to radio B. The mode signal indicates the state of each radio during each 750 μ s time slot. The payload for the two packets (Pkt0a and Pkt1a) to be transmitted is moved into the transceiver's internal buffer from the microcontroller at $t=0\mu$ s. 750 μ s later the transceiver for radio A is transitioned to transmit mode and, after a startup delay, the two packets are transmitted. At this time radio B will also be receive mode. When the packets are decoded by radio B, the payload is buffered in the transceiver until it can be read by the microcontroller at $t=1.5$ ms.

This figure also shows that each packet is transmitted twice. Pkt1a is first loaded into the transceiver of radio A at $t=0$ s, and again 1.5ms later. All packets are identified by a 4-bit sequence number and by an additional bit that identifies a packet as a retransmission of a previous packet. By checking these values the microcontroller is able to keep track of statistics, such as the number of dropped packets which would be indicated by a gap in sequence numbers between packets. The signal strength indicator on the home screen on the LCD is calculated from the number of dropped packets.

Byte	Name	Description
0	ACK information	Bits 7-5 – Reserved for future use. Bit 4 – Acknowledge enable (1), or disable (0) Bits 3-0 – Sequence number of last packet from other radio to acknowledge.
1	Packet Header	Bits 7-6 – Packet type, default 00. Reserved for future use Bit 4 – Original transmission (1), or retransmission (0) Bits 3-0 – Sequence number.
2-13	Analog 0 Data	Twelve bytes of data from analog input 0 (8-bit wide samples), first sample first
14-25	Analog 1 Data	Twelve bytes of data from analog input 1 (8-bit wide samples), first sample first
26-31	Digital Data	Six bytes of data from digital inputs (4-bits per sample), two samples per byte Byte 0 Bits 3-0 – Sample 0 Byte 0 Bits 7-4 – Sample 1 Byte 1 Bits 3-0 – Sample 2 ... Byte 5 Bits 7-4 – Sample 11

Figure 3-2 Payload Description

The table above describes the format of a packet's payload as seen by the microcontroller. In addition to this payload, the transceiver IC appends a 16-CRC and an 11-bit address. If a packet is received by a transceiver and the address does not match or the CRC fails the packet will be discarded automatically.

Every packet contains 32 bytes of payload, 30 bytes of which are used to store analog and digital samples. This is enough to store 12 samples worth of data (2 8-bit analog channels + 4 1-bit digital channels). The acknowledge information is not currently used, but was included for future expansion.

Radio Synchronization

In order for the radios to communicate the transmission time slots between the two radios must be synchronized. If the 750 μ s transmission time slots overlap by more than 40 μ s the link will fail.

After initial power up the radios enter a search state where they listen for a packet from another radio to synchronize with. Instead transmitting packets every 1.5ms, when a radio is in search mode it transmits a packet every 23.25ms and spends the rest of the time in receive mode.

Every time a radio decodes a valid packet an interrupt is thrown from the transceiver to the microcontroller. When this occurs the microcontroller reads an internal timer and compares the time the packet was received to the time the microcontroller expected to receive the packet. The microcontroller then sums the error from the last sixteen received packets. If this error is too high the microcontroller's timer is reset to resynchronize the radios. The transmission timing for the radio is derived from this timer, by changing its value the time until the next transmission time slot can be adjusted as well.

User Interface

The user interface for the radio module consists of a character LCD and four tactile switches. Through these the user is able to select the radios frequency, transmit power, and is able to place the module into a sleep state.

All UI processing takes place in the program main thread. An infinite loop continuously checks the state of the push buttons and refreshes the LCD when necessary. When the channel or transmit power are changed by the user flags are set to inform the sampling ISR to reconfigure the radio. The radio is not directly configured in the main thread to prevent resource conflicts.

TI-FET debugger or equivalent

New firmware may be downloaded to the MSP430 microcontroller using a TI-FET or equivalent JTAG adaptor and the IAR Embedded

Workbench software. An evaluation copy of Embedded Work bench is available at: <http://supp.iar.com/Download/SW/?item=EW430-EVAL> .

Since the current firmware image is greater than 4kb, the evaluation or the fully licensed version of Embedded Workbench is required. The Kickstart edition will not work.

To download firmware onto the MSP430:

1. Open IAR Embedded Workbench
2. Connect the JTAG interface to the computers Parallel port and to the radio module
3. Power the radio module using either batteries or an AC adaptor.
4. On the Workbench menu bar, click *File-> Open -> Workspace*
5. Locate the project folder and select: *Cpre491_new.eww*
6. After the project has loaded, the firmware image can be downloaded by pressing [CTRL] + [D]
7. This key sequence downloads the firmware image and starts the debugger, exit the debugger by pressing [CTRL] + [SHIFT] + [D]

Testing

4

The Universal Communications Link can be tested during assembly and after being programmed. The following test procedure should be followed if the communications link does not perform as expected. For testing procedure during assemble, please refer to Chapter 3 Assembly, section, Assembly Procedure.

After Assembly

The first stage of testing after assemble is to visually inspect the radio module for defects. Some defects include bad PCB traces, missing/misaligned/damaged components, and poor/no solder joints. The visual inspection should catch most assembly errors. A list of critical checkpoints can be found in the list below.

- o Damaged components
- o Incorrect components
- o PCB traces
- o Missing components
- o Misaligned components
- o Solder joints

Hardware Testing

The second stage of testing will be to verify individual components on the PCB are working properly. Due to the scope of this project, a large majority of hardware testing requires software being debugged; however, initial testing of all systems can be performed without software as follows. Each of the following tests require at minimum a multimeter which is capable of measuring voltage and current and an oscilloscope which has a 10MHz bandwidth. All voltages are referenced to the ground (GND) test point on the PCB. The radio module must have access to power either through the batteries or DC power unless otherwise noted. This stage of testing will only be implemented on the prototype design; however, if the end-product design does not pass the functionality testing, these checklists shall be implemented to locate the problem.

Microcontroller Checklist

- o Voltage measured between the microcontroller pins 1, 25, 58 and the test ground pad must be within the range of 3.27 and 3.33V.

- o Voltage measured between the microcontroller pins 11, 52, 62, 63 and the test ground pad must not exceed 0.03V.
- o 8 MHz clock measured between pins 8 and 9 must be present and operating within 5% of 8 MHz.

User Interface Checklist

- o Voltage measured between the microcontroller pins 13, 14, 15, 16 and the test ground pad must be within the range of 3.27 and 3.33V when the corresponding button is pressed.
- o The settling time of each button must reach a stable response within 750 μ s. If this does not happen, the tactile switch may need replacement.
- o Voltage measured between the LCD pin 1 and the test ground must be within the range of 3.27 and 3.33V.
- o Voltage measured between the LCD pin 2 and the test ground must not exceed 0.03V.
- o Voltage measured between the LCD pin 4 and the test ground should be within the range of 0 to -1V. (Dependent upon LCD contrast)

Power Subsystem Checklist

- o When the external DC power source is not present, the internal batteries provide power to the circuitry; therefore should be within the range of 3.6 and 4.5V depending upon the charge on the batteries.
- o When the external DC power source is present, the external source provides power to the circuitry; therefore should be within the range of 5 and 10V depending upon the source.
- o Irregardless of the power source present, the voltage measured between the voltage out test point and the ground test point must be within the range of 3.27 and 3.33V.
- o Battery current <10 μ A test may be omitted due to the fact the current measurement must be made in series with the batteries which means the batteries must be accessed during this test.

Transceiver Checklist

- o Voltage measured between pin 1 of JP5 and the test ground pad must be within the range of 3.27 and 3.33V.
- o Voltage measured between pin 8 of PJ5 and the test ground pad must not exceed 0.03V.

Functional Testing

Range Test- This test is to measure the number of RF packets lost (digital & analog data) over a one second time period. The radio modules are placed in an open field and are in line of sight of one another. The distance between the radio modules is slowly walked off as the number of RF packets lost is measured. Once the number of drop packets has become great enough as to cause the radio modules to cease communication with each other, the distance between them is measured and the range recorded.

Power Test- This test is to measure the current that the radio module is using when it is in its sleep and transmit/receive modes, as well as check the power switchover time from external to internal power. These measurements are done with the help of a multimeter and are recorded. These values should not exceed the specifications define by the project team.

User Interface Test- This test is to perform regression testing of the interface, verify that the LCD is contrasted correctly and clearly seen, and to check that the non-volatile memory of the LCD works. Regression testing is done to check newly implemented software that previously worked as desired, but has stop working or no longer works in the same way as seen in previous versions of the code. The readability of the LCD is visually inspected and adjusted as needed. The non-volatile memory of the LCD is checked by selecting different channel and power configurations other than the default settings. These settings should then be displayed by the LCD in the home screen. If the radio module is powered off and later powered back on the LCD should still display these same values and not reset to the default configurations.

Waveform validation- This test is to measure the corner frequencies of the analog filters, and verify the signal integrity from the input of one radio module to the output of another. An oscilloscope is used to confirm that the signal seen on the input pin of the first radio matches with the output pin of the second.

User Test- This test is to have the client use the radio modules with only the help of the user manual to guide them. Successful results will ensure that the user manual does explain correctly and clearly on how to operate the radio modules. If the client encounters problems using the modules, the user manual will be adjusted accordingly.

Troubleshooting

5

The section is intended to aid the user in troubleshooting the communications link.

Power subsystem

External DC power source not present, internal batteries present.

1. Voltage on pin 1 of Texas Instruments TPS78833 voltage regulator should be within range of 3.6 and 4.5V; if not replace component U1, dual P-channel FET.
2. Voltage of pin 5 of Texas Instruments TPS78833 voltage regulator should be within range of 2.9 and 3.3V; if not replace component U2, voltage regulator.

External DC power source present, internal batteries not present.

1. Voltage on pin 1 of Texas Instruments TPS78833 voltage regulator should be within range of 3.6 and 10V referenced to GND test pad; if not replace component D13, Schottky diode.
2. Voltage of pin 5 of Texas Instruments TPS78833 voltage regulator should be within range of 2.9 and 3.3V; if not replace component U2, voltage regulator.

User Interface

LCD does not display

1. Verify pin 1 of LCD is within the range of 3.27 to 3.33V referenced to GND test pad, if not refer to troubleshooting power subsystem of this section.
2. Verify pin 2 of LCD is within the range of 0 to 0.01V referenced to GND test pad.
3. Verify pin 3 of LCD is within range of 0 to -1V referenced to GND test pad, if not replace component U5, level translator.
4. Verify pin 6 of LCD is pulsing, if not refer to troubleshooting Microcontroller of this section.
5. Verify pins 7-14 of LCD is pulsing after a button pressed, if not refer to troubleshooting Microcontroller of this section.

Microcontroller

1. Check that the pins of the MCU are connected correctly, see PCB schematic in this manual.
2. Check that the MCU has a voltage input level of approximately 3.3V.
3. Check the MCU clock pin 57, to ensure the clock is running properly.
4. Check that the MCU is properly programmed with the JTAG connector, if the JTAG doesn't communicate with the MCU a possible replacement of MCU is needed.

Transceiver

1. Check the pins of the transceiver chip are connected correctly; see PCB schematic in this manual.
2. Check that the transceiver chip has a voltage input level of approximately 3.3V.
3. Check to see if the transceiver output pins to see if the chip can communicate with another working radio using a spectrum analyzer.

Notes

Notes
